MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2017/2018

EEL2216 – CONTROL THEORY

(All sections / Groups)

4 JUNE 2018

9.00 a.m. – 11.00 a.m.

(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **SIX** pages including cover page with **FOUR** questions only.

2. Answer **ALL** questions and print all your answers in the answer booklet provided.

3. All questions carry equal marks and the distribution of the marks for each question is given.

Question 1

(a) Consider the unity feedback system shown in Figure Q1(a).

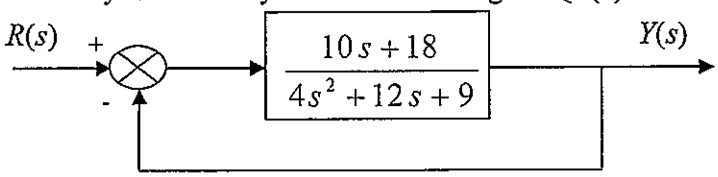

Figure Q1(a)

(i) Find the zeros and poles of $F(s)=\dfrac{10s+18}{4s^2+12s+9}$. [2 marks]

(ii) Determine the values of A and B, when $F(s)$ is written in form of $F(s)=\dfrac{A}{2s+3}+\dfrac{B}{(2s+3)^2}$. [6 marks]

(iii) Using inverse Laplace transform, determine $f(t)$. [3 marks]

(b) Derive the closed-loop transfer function $Y(s)/R(s)$ for the block diagram shown in Figure Q1(b) by using the block diagram reduction method. Show your method step by step. [5 marks]

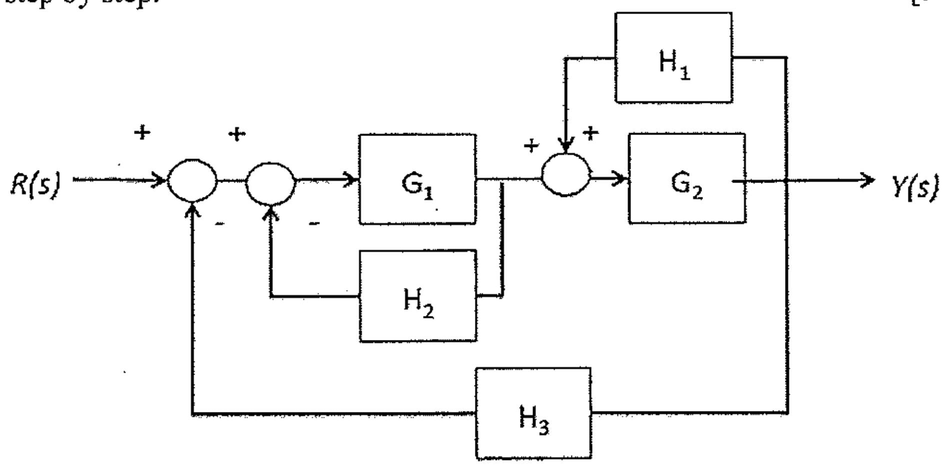

Figure Q1(b)

(c) Derive the transfer function y_5/y_1 for the signal flow graph as shown in Figure Q1(c) by using Mason's rule. [9 marks]

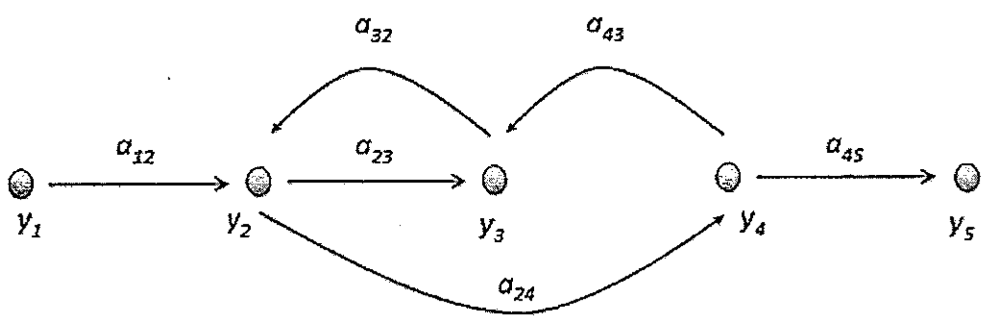

Figure Q1(c)

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Question 2

(a) Briefly explain the Routh-Hurwitz (RH) criterion for the determination of system stability. [3 marks]

(b) The closed-loop transfer function of a second order system is given below, where $Y(s)$ is the output while $R(s)$ is the input:

$$\frac{Y(s)}{R(s)} = \frac{K}{(s+0.5)(s+\beta)+K}.$$

Find K and β such that the delay time, t_d, is 5s and rise time, t_r, is 8s. (Given that $t_d = \frac{1+0.7\zeta}{\omega_n}$ and $t_r = \frac{0.60+2.16\zeta}{\omega_n}$. ζ and ω_n are the damping ratio and natural undamped frequency, respectively). [8 marks]

(c) A negative unity feedback amplifier system has the following loop transfer function:

$$KG(s)H(s) = \frac{K(s+2)}{(s+1)(s+5)(s+8)}.$$

Determine the following:

(i) The starting and ending points. [2 marks]

(ii) The number of branches. [1 mark]

(iii) Behaviour at infinity. [2 marks]

(iv) Root loci on the real axis. [1 mark]

Given that the break-away point on the real axis is **-6.45**, sketch the root locus of the system. What is the range of K for stability? Give your reason. Predict the effect of adding a pole to $G(s)H(s)$ on the root locus of the system above. [4+4 marks]

Question 3

(a) The forward path transfer function of a unity-feedback control system is given as:

$$G(s) = \frac{24}{(s+2)(s+6)}.$$

(i) Analytically calculate the resonance peak, M_r and its resonant frequency, ω_r of the closed-loop system. [5 marks]

(ii) What is the relationship between M_r and damping ratio, ξ? [2 marks]

Continued...

(b) Consider the following transfer function:

$$G(s)H(s) = \frac{5}{s(s+3)}.$$

(i) List out all the basic factors and their corresponding corner frequencies, magnitudes/slopes and phases. [10 marks]

(ii) Sketch the Bode asymptotic magnitude and asymptotic phase plots **accurately** on a semi-log paper. [6 marks]

(iii) Based on part(b)(ii), estimate the phase margin (PM) and its corresponding gain crossover frequency (ω_{gc}). [2 marks]

Question 4

(a) There are various controller/compensator configurations in control system compensation such as cascade compensation and feedback compensation.

(i) Draw the configurations for cascade compensation and feedback compensation. [4 marks]

(ii) State one advantage of feedback compensation over cascade compensation. [2 marks]

(b) The unity feedback system shown in Figure Q4 has a controller $K(s)$ and a plant transfer function $G(s)$ given by:

$$G(s) = \frac{1}{(s+3)(s+7)}$$

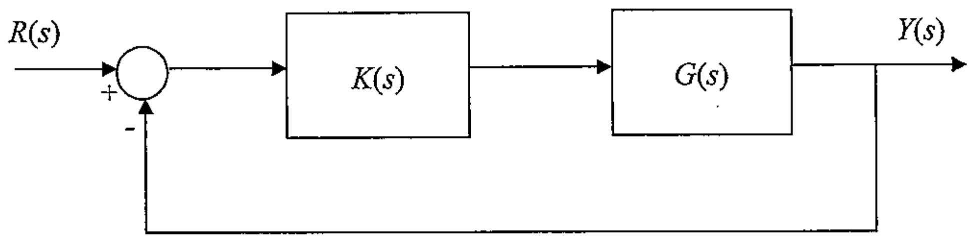

Figure Q4(b)

Design the following:

(i) A Proportional Derivative (PD) controller, $K(s) = K_P + K_D s$ such that the damping ratio is 0.85 and the steady-state error of the cascaded system is 5% for a unit step input. [8 marks]

(ii) A lead compensator controller, $K(s) = \frac{B(s+z)}{(s+p)}$ if the system have dominant poles at $s = -7 \pm j20$ and a compensator pole at s = -10 (i.e. p = 10). [11 marks]

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Appendix - Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
$t^n \ (n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \ (n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$

Continued...

Appendix - Laplace Transform Pairs (continued)

$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}\,t$	$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t-\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n^2}$
$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\quad(\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Paper